COST BENEFIT ANALYSIS FOR MATERIAL MANAGEMENT GROUPS

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1.0 Background

The Nonactinide Isotope and Sealed Sources Management Group (NISSMG) is sponsored by the Department of Energy (DOE) Office of Environmental Management and managed by Albuquerque Operations Office to serve as a complex-wide resource for the management of DOE-owned Nonactinide Isotope and Sealed Source (NISS) materials. NISS materials are defined as including (1) any isotope in sealed sources or standards and (2) isotopes with atomic number less than 90, regardless of form. The NISSMG assists the DOE sites with the storage, reuse, disposition, transportation, and processing of these materials.

The NISSMG is one of five material management groups (MMGs), with the others being Plutonium, Uranium, Heavy Isotopes, and Spent Nuclear Fuel. These groups were created by the Deputy Assistant Secretary for the Office of Environmental Management's (EM's) Office of Integration and Disposition (EM-20) to ensure integration of nuclear materials activities across the DOE complex. In fiscal year 2001, the Nuclear Materials Council (NMC) initiated a pilot study to evaluate these MMGs in terms of both the cost and benefits of their activities in order to determine if these groups should be institutionalized as corporate resources. This report documents guidelines developed by the NISSMG to provide a consistent basis for this analysis.

2.0 Introduction

These guidelines for preparing a cost-benefit analysis (CBA) are designed to provide a relatively simple approach to the process of CBA, and to establish a standardized way to approach the costs and benefits of different MMG projects. The guidelines presented here provide further detail for the decision evaluation method of CBA as identified in the Guidebook to Decision-Making Methods.[1] The Decision Support Guidebook contains a more generic discussion of the CBA approach as well as other decision support methodologies. In addition, the Guidebook provides a discussion of preliminary steps for evaluation of decisions that are important for any evaluation method. Analysts developing CBAs for MMG pilot projects are encouraged to perform these preliminary steps in the Guidebook (2.1 through 2.6) before proceeding with their analyses.

[1] *Guidebook to Decision-Making Methods*. Developed to support the Department of Energy Integrated Nuclear Materials Management (INMM) Plan, September 2001 Final Draft.

The preliminary steps are[2]

1. Define the problem
2. Determine requirements
3. Establish goals
4. Identify alternatives
5. Define criteria
6. Select decision-making tool

The CBA process provides a decision rule for evaluation and selection of MMG activities. The general decision rule is to 1) continue, or start, those activities that are estimated to have positive net benefits, and 2) given budget constraints, select the set of activities within budget that yield the largest sum of net benefits.

The CBA guidelines list several cost and benefit elements that are likely to occur in MMG activities. However, the lists are not intended to be comprehensive guidelines since different activities may involve different costs and benefits. As a result, CBAs for different MMG activities can include cost or benefits not listed here, or can drop some of the provided elements.

The CBA guidelines take the user through a series of steps intended to make the results clear and credible to anyone reviewing the CBA. In addition, the Decision-Making Methods Guidebook's Section 2, as discussed above, provides a discussion of preliminary steps to provide a basis where the CBA methodology can be used. Once the baseline and alternative cases are defined, impacts (both positive and negative)are defined for the cases. These impacts are catalogued and estimated over the time frame of the MMG activity. Dollar values for the negative impacts (costs) and positive impacts (benefits) are determined. The cost and benefit profiles over time are then discounted to obtain present values, and combined for the baseline and alternatives to obtain net present values (NPVs). Some costs or benefits may occur because of an MMG activity, but may be difficult to assign over time. These impacts should be cataloged but be kept separate from the NPV calculation since discounting is not done. Finally, a sensitivity analysis is performed for each CBA, particularly where NPVs are close in value. CBA conclusions are given based on the NPVs and the sensitivity analysis.

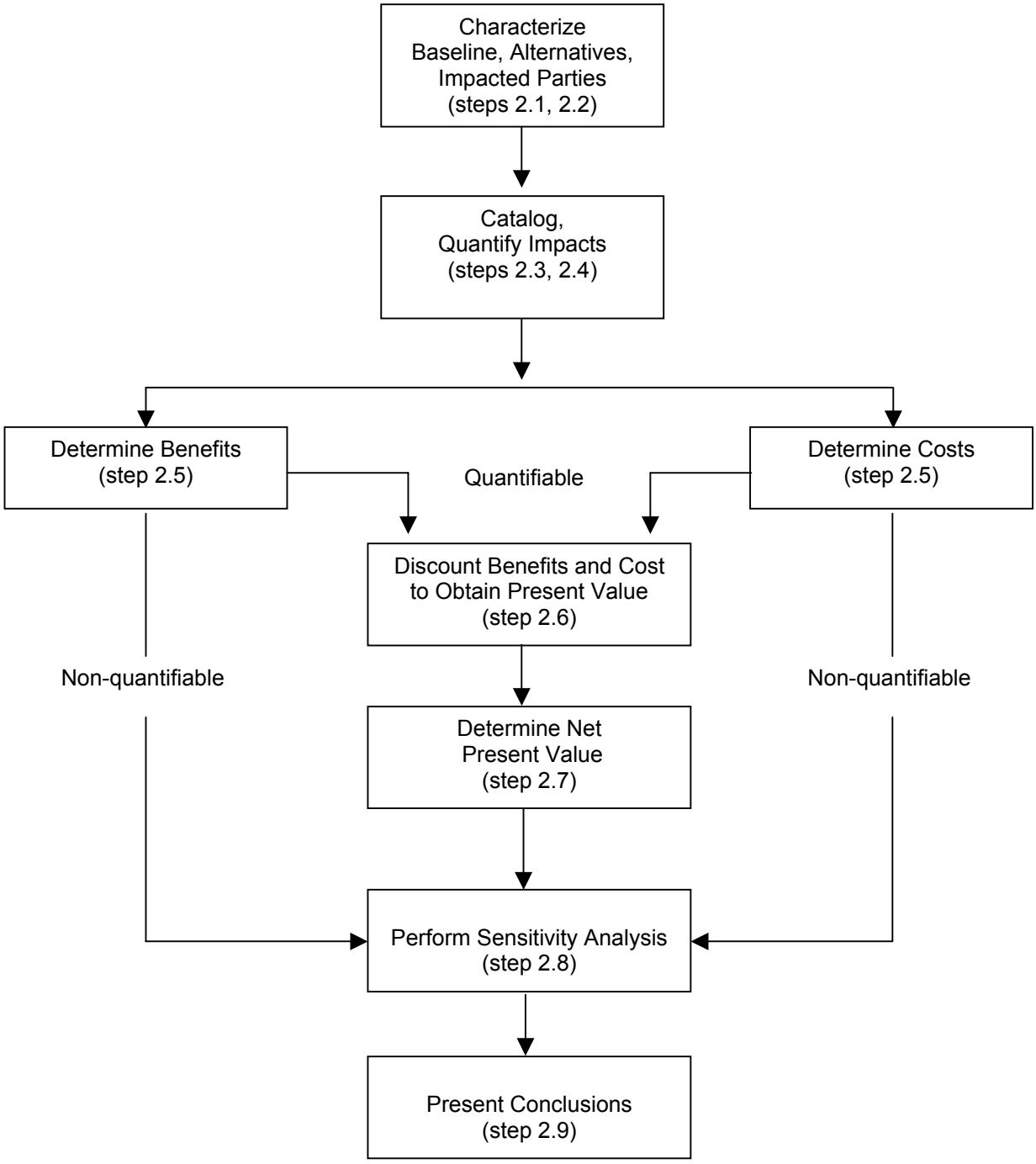
The last section of the CBA Guidelines includes a general listing of costs and benefits that can be collected as an MMG activity is initiated. Once an MMG activity is under way it is difficult to collect the appropriate information for the CBA because cost or benefit information from early in the activity may not have been collected, or an important measure was not identified until well into the activity.

[2] Additional detail on the six-step process is provided in Appendix C.

2.0 The CBA Process

Figure 1 shows the 9-step procedure for development of a CBA. These steps are described in detail in the sections that follow.

Figure 1. Cost Benefit Process



2.1. Characterize baseline and alternatives.

The purpose of this step is to explain the context and expected results of the MMG activity to be evaluated using CBA. This information is available in the MMG Pilot Project Plans.

- Activities - describe the MMG activity under consideration. The description should be comprehensive but simple enough that those unfamiliar with the activity can understand its scope. If alternatives include different activities than the baseline, describe those separately.
- What is the problem, desired state, and goals for the given issue being analyzed. Goals may differ across DOE Offices for an activity. List all goals associated with the activity.
- Technical approach - describe the technical approaches planned in the baseline and the alternatives. If the technical approaches are the same in all cases, characterize what differentiates the baseline and alternatives scenarios.
- Project length - provide estimates for each case.

2.2. Decide whose costs and benefits will count.

The impacts of a MMG activity are likely to affect different parts of society. For example, an alternative MMG activity that results in cost avoidance provides a benefit at the Federal level. Other Federal agencies, such as the EPA, may experience avoided costs if monitoring is reduced. In addition the alternative may impact state and local entities. State regulatory cost may be avoided because of less oversight needs, while localities experience negative impacts because of DOE labor force reductions. However, the local work force may benefit from lower dose commitments, and local property values may rise as site closure proceeds.

While it is impractical to list and quantify all potential impacts, the credibility of the CBA will be enhanced if assumptions about whose impacts are included and whose are excluded in the study are explained. The main focus here is on impacts to DOE. Under the MMG Pilot Project, impacts - costs and benefits - will directly affect DOE Offices. Table 1 illustrates a simple format for summarizing these core MMG activity impacts.

Table 1. Example of Distribution of Core MMG Activity Impacts

	DOE Office				
Impacts	Environ-mental Management (EM)	Office of Nuclear Energy (NE)	Office of Defense Programs (DP)	Office of nonprolif. and nat. security (NN)	Office of Science (SC)
MMG resources					
Site/program resources					
Disposition resources					
Specific objective completion					
New materials in circulation					
Contingencies reduction					
Early ID of potential problems					

Depending on the MMG activity, some cells in Table 1 will be zero, since all DOE Offices will not be affected equally by the core impact elements.

2**.3. <u>Catalog impacts of alternatives and select measurement indicators</u>**.

The purposes of this step and step 2.4 are to describe in a credible easily understood manner the types of impacts or changes the alternatives would bring compared to the MMG activity baseline. Establish quantitative measures of the impacts where feasible, and estimate the incidence of impacts over the project life. The type of impacts of concern to the Department of Energy in these CBAs are those affecting the offices of EM, DP, NN-60, NE, or NN. Both real costs and avoidances are to be considered. The impacts of the alternatives include direct changes in resource requirements (labor, equipment, facilities), changes in site conditions such as programmatic risk, and indirect effects for alternatives compared to the baseline. Impacts can be positive (benefits) or negative (costs).

Since impacts are changes from the baseline, baseline conditions need to be characterized. Ideally the baseline characterization will contain information that will provide comparison with each impact element. At times, the baseline is not executable without additional activity. Prior to the alternative comparisons, add required activity and costs to the baseline such that an “apples to apples” comparison can be performed.

The detailed activities and resulting impacts begin to provide the positive and negative differences in the alternatives that can be used to measure benefits and costs once dollar values are assigned. Direct impacts are specifically associated with the MMG activity. An example using the core impacts listed in Table 1 is shown in Table 2.

Table 2. Examples of Potential Direct Impacts of Alternatives

Impacts	Baseline	Alternative #1	Alternative #2	Comments
MMG resources				
Site/program resources				
Disposition resources				
Specific objective completion				
New materials in circulation				
Contingencies reduction				
Early ID of potential problems				

Some of the core impact categories can require further breakdown. For example, site/program resource impacts can be broken into impact categories shown in Table 3. Measurement indicators include changes in full time equivalent (FTE) labor requirements, materials requirements, and square footage of facilities by impact element.

Table 3. Site/program Resource Impacts

• Operation and maintenance (O&M)	• Packaging and transportation
• Facility and infrastructure	• Certification
• Safeguards and security (S&S)	• Final disposal
• Research and development	• Support

Other direct impacts can be added as they are identified. In addition, indirect impacts may occur for some MMG activities. Indirect impacts are those that impact other MMG activities or conditions. Such impacts occur because of activities which are not present in the baseline, are not directly associated with the MMG activity, or are associated with more than one activity. Some examples are given in Table 4.

Table 4. Examples of Potential Indirect Impacts of Alternatives

• Budgets for other MMG activities	• Property values
• Community attitude toward MMG activity	• Mission/site employment
• Mission/site schedule	• State, local support requirements

The possible set of indirect impacts for any MMG activity is large. Based in familiarity with the activity, reasonable judgement should be used to select and explain any indirect benefits included.

Indirect impacts are often more difficult to quantify and to ultimately assign dollar values. However, it is valuable to list these impacts. Note and discuss important impacts in a qualitative context if quantifying is not feasible or acceptable. Qualitative description and discussion of hard-to-measure impacts can still add important information for CBA reviewers and decision-makers. An example of a CBA summary that includes qualitative measures is presented in Appendix A.

2.4. Quantify impacts over the life of the project.

Once impacts are quantified and placed in time, the basic underlying structure of the CBA is in place. Impacts are quantified in terms of changes in FTEs, materials and facilities, schedule, quantities of new products, contingencies, and any other quantifiable differences from the baseline that are created by alternatives.

An identified impact element can involve more than one quantified impact measure. For example, a MMG activity alternative that has a positive impact on O&M could decrease the annual FTE requirement and maintenance supplies from the baseline situation.

Most MMG activities have impacts that extend over time. To permit meaningful comparisons of the baseline and the alternatives it is important to present the streams of impacts over time. It is informative to lay out the impacts of a MMG baseline and alternative activities on a yearly time line. The time line is based on the project life described in Step 2.1. A time line clarifies the timing of impacts, and highlights impacts that are present but difficult to locate at a particular point in time. For example, the community attitude toward an MMG activity may be an important indirect impact but difficult to assign to any year.

Quantifying impacts over time requires:

- Establish quantified measures over the project life for the baseline based on the impacts cataloged in Step 2.3. As noted above, some impacts may not fit into a timeline, while others will be qualitative.
- Develop quantified measures over the project life for the changes or impacts to the baseline measures resulting from an activity alternative. Provide qualitative assessments of impacts that are not quantified. Impacts are determined for each alternative separately.

Table 5 shows a sample illustration, using the core impacts in Table 1, for listing impact categories and annualized quantitative impacts over the life of the MMG project. As noted above the impacts are estimated changes from the baseline requirements. The number of years included is established by the project life of the alternative.

Table 5. Annualized Core MMG Impact Categories

Impacts	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
MMG resources						
Site/program resources						
Disposition resources						
Specific objective completion						
New materials in circulation						
Contingencies reduction						
Early ID of potential problems						

Some impacts cannot be allocated on an annual basis. For example, avoided resource use as a result of an earlier project completion date in a MMG alternative is a positive impact, but may not accrue annually. Many benefits, such as early identification of potential problems, also do not fit easily in an annualized framework. Non-annualized impacts should be listed and quantified if possible for the alternatives. These impacts, whether characterized in a quantitative or qualitative manner, should be considered when performing sensitivity analysis.

2.5. Attach dollar values to impacts to establish costs and benefits.

Dollar values need to be attached to the annualized impacts and, to the extent possible or acceptable, to impacts that accrue to the overall MMG alternative projects. Annualized benefits and costs should be calculated separately. Table 6 is a sample template for listing annualized direct benefits in dollars, and follows from Table 5. A similar table can be used to calculate cost impacts for each alternative.

Table 6. Annualized Core MMG Activity Benefits of Alternatives

Element (FY2001 $)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Site/program resources						
Disposition resources						
Specific objective completion						
New materials in circulation						
Contingencies reduction						
Early ID of potential problems						

As noted, there are impacts where attaching a dollar value for a benefit or cost is not feasible or acceptable, or difficult to annualize. These impacts should be incorporated into the overall summary of the CBA, and considered in the sensitivity analysis.

2.6. Discount for time to find present values.

Discounting to establish present value (PV) for costs and benefits of the baseline and alternatives provides a common measure to compare actions with different timing of activities. The costs and benefit streams over time in Table 6 are discounted using discount rates set by the Office of Management and Budget in OMB Circular No. A-94.[3] Discount costs and benefits separately.

The recommended discount rate for the CBA is the real (inflation excluded) social rate of time preference, which reflects the discount rate at which society is indifferent between receiving payment now and a correspondingly larger payment in a future year. OMB sets this real annual discount rate at 3.2 percent, or roughly 3 percent. Discount factors for 3 percent are listed in Appendix B.[4]

Table 7 shows a hypothetical example of benefits from cost avoidance for upgrading facilities and infrastructure over a 5-year project life, with the 3 percent discount factors from Appendix B applied to calculate discounted benefits (DB).

Table 7. Discounting Example

Facilities and Infrastructure	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	
Annual benefits	$15,000	$20,000	$25,000	$30,000	$35,000	
Discount factors	0.9709	0.9426	0.9151	0.8885	0.8626	**Total**
Discounted benefits	$14,564	$18,852	$22,878	$26,655	$30,191	$113,139

2.7. Sum up discounted benefits and cost to determine net present value.

Once the discounted costs (DC) and discounted benefits (DB) are derived, discounted net benefits (DNB) for each year *t* are calculated as

[3] U.S. Office of Management and Budget, OMB Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs,* October 1992.

[4] The present value of a cost or benefit of Y dollars after n years is $PV_n = Y/(1 + r)^n$ where r is the real discount rate.

$$DNB_t = \sum_{i=1}^{n} DB_{it} - \sum_{j=1}^{m} DC_{jt}$$

where there are *n* benefit elements (for example, the 6 elements in Table 6), and m cost elements. The net present value for an alternative is then found by adding up the DNBs for the life of the activity, or

$$NPV = \sum_{t=0}^{k} DNB_t$$

where k is the project life in years.

If the benefits or costs of the baseline and alternative are long-lived, extending far into the future, a "terminal value" can be included that aggregates the extended stream of impacts. The generally accepted way to include a terminal value for an alternative is to include it as an additional term, using the following formula to compute NPV:

$$NPV = \sum_{t=0}^{k} DNB_t + T(k)$$

where *T(k)* is the estimated net present value of all benefits and costs that occur after the k-year life of the project. Because of the uncertainty associated with *T(k)*, sensitivity analysis is usually conducted on the estimated value.

The NPV calculation and other impacts that have not been assigned dollar values or are qualitative can be combined in a summary accounting table. An example is given in Appendix A.

2.8. Perform sensitivity analysis.

The results of the CBA can achieve increased credibility through sensitivity analysis of important parameters and assumptions used in the CBA. Sensitivity analysis can be performed on:

- Discount rate
- Major benefit or cost drivers
- Least well-defined costs, benefits (highest uncertainty)
- Qualitative measures of benefits and costs
- Terminal value

The CBA process tends to submerge uncertainty by using the most plausible estimates to determine impacts. The purpose of sensitivity analysis is to recognize and discuss such underlying uncertainties. In particular, the analysis should convey how sensitive the CBA is to changes in key parameters and assumptions. There are several procedures used in sensitivity analysis. Two

are suggested here: partial sensitivity analysis, and worst case/best case analysis.

Partial sensitivity analysis addresses the question: How do net benefits change as a single parameter or assumption is varied while holding all others constant? For example, the discount rate could be increased, while other factors are left unchanged, until the NPV for the alternative reaches zero. The analysis would be repeated for all important parameters and assumptions, and the results cataloged.

However, the partial analysis approach becomes more difficult to use when qualitative parameters or assumptions are involved. In these cases, worst case/best case analysis may convey more information. A credible lower bound on net benefits of an MMG alternative can be obtained by considering the least favorable of the plausible range of values for the parameters or assumptions. Similarly, the most optimistic prediction of net benefits can be calculated using the most favorable values or assumptions. Typically worst-case analysis is used when the original CBA yields a positive NPV, and best-case analysis is used when the original NPV is negative.

2.9. Present conclusions based on NPV and sensitivity analysis.

Generally the CBA conclusions should recommend the baseline or alternative that has the highest NPV. However, most CBAs require important caveats for the original CBA, including the results of the sensitivity analyses. Cost-benefit calculations become less credible when baselines are undefined or poorly defined, since the NPVs for the alternatives are calculated from changes or impacts alternatives create compared to the baseline. Conclusions should include a description of the activity or project, major assumptions, baseline and alternatives (including assessment of their accuracy), a summary table of CBA results, sensitivity analysis, and discussion of which alternative is recommended.

3.0 Measures of Costs and Benefits

Table 8 provides a general list of potential costs and benefits that may be associated with an MMG activity. Several of the measures have been included in the example tables given in the step-by-step description of the CBA process presented in section 2. The table provides representative cost and benefits.

The list should be viewed as a "check list" that provides cost and benefit measures that may apply to the activity, and should be addressed at the beginning of the project. Establishing a list of potential costs and benefits at the beginning of an MMG activity provides the opportunity to structure the data collection processes for the identified measures. In cases where measures are not quantified, collection of information throughout the MMG activity provides a basis for better qualitative discussion of the measures.

Table 8. Potential Cost and Benefits Measures

Costs	Benefits
Facility/landlord: • Operation and maintenance • Storage • ES&H • Security • Regulatory compliance	Facility/landlord: • Project completion • Increased operational efficiency • Early identification of problems • Reduced site support requirements
Disposition: • Characterization • Treatment • Packaging • Disposal	Disposition: • New materials in circulation • Risk reduction • Lower dose commitment
MMG support	Maturing of pilot R&D activities
Cost impacts on other facilities, sites	Reduction in overall DOE site needs

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Appendix A

Cost Benefit Summary for Deployment of a Mobile Tank Waste Retrieval System Employing Small Waste Tanks

ATTRIBUTE	IMPACTS		
Description	Baseline	Fluidic Mixer	Comment
Project Cost (2 years)	$1,792,963	$946,384	
Regulatory Compliance	Not quantified, possibly significant	Not quantified, probably negligible	Compliance cost associated with worker dose during mixer replacement operation higher for mechanical system
Disposal costs			2 mechanical mixer replacements during ten years
Total risks			Dominated by worker radiological dose during mixer transfor and installation
Worker risk/installation, repair and maintenance, radiological	0.2 man Sv = $46,000 3 installations = $138,000	0.006-0.018 man Sv = $1,200-3,600	Dose most significant during installation operation, and is greater for baseline technology
Worker risk/operation	Significant as a result of proximity to tanks and need to wear protective suits	Negligible	
Public risk/operation	None	None	No failure mode leading to off-site release
Worker risk/disposal	Uncertain, perhaps of the order of 0.2-0.3 man Sv	Uncertain, perhaps of the order of 0.01 man Sv	Higher for baseline technology that requires more frequent and complex disposal operations
Public risk/disposal	Possible/minor	Possible/minor	
Environmental			
Materials use/supply		1000-3000 lb.	Steel components
Materials use/operation, power requirement		1.4×10^6 kWh	
Wastes on disposal		2 m^3 HLW	
Plant availability		Extremely high	

APPENDIX B
Discount Factors for 3%

Year	Discount Factor	Year	Discount Factor
1	0.9709	16	0.6232
2	0.9426	17	0.6050
3	0.9151	18	0.5874
4	0.8885	19	0.5703
5	0.8626	20	0.5537
6	0.8375	21	0.5375
7	0.8131	22	0.5219
8	0.7894	23	0.5067
9	0.7664	24	0.4919
10	0.7441	25	0.4776
11	0.7224	26	0.4637
12	0.7014	27	0.4502
13	0.6810	28	0.4371
14	0.6611	29	0.4243
15	0.6419	30	0.4120

Appendix C
Steps in the Decision-Making Process

NOTE: The decision-making steps described here is based on the process defined in Section 2, pp. 3-5 of the *Guidebook to Decision-Making Methods,* Developed to support the Department of Energy Integrated Nuclear Materials Management (INMM) Plan, September 2001 Final Draft.

1. **Define the problem** - Problem definition is the crucial first step in making a good decision.The decision-maker and support staff must express the problem in a clear *problem statement* that describes:

   - the mission
   - initial conditions
   - desired conditions
   - needs of the stakeholders

   The decision-maker and support staff must concur on a written problem statement and assumptions to ensure that they all know what problem is going to be solved. If stakeholders are involved, they can review the problem statement with its initial and desired state to provide an external check before requirements and goals are defined.

2. **Determine Requirements -** Requirements are conditions that any acceptable solution to the problem must meet. Requirements spell out what the solution to the problem must do. For example, a requirement might be that a process must ("shall" in the vernacular of writing requirements) produce at least ten units per day. Any alternatives that produced only nine units per day would be discarded. Requirements that don't discriminate between alternatives need not be used at this time.

   With the decision-maker's concurrence, experts in operations, maintenance, environment, safety, health and other technical disciplines provide the requirements that a viable alternative must meet.

3. **Establish Goals -** Goals are broad statements of intent and desirable programmatic values. Examples might be: reduce worker radiological exposure, lower costs, lower public risk, etc. Goals go beyond the minimum essential "must have's" (i.e. requirements) to *wants* and *desires*. Goals should be stated positively (i.e. what something *should do,* not what it *should not do*). Because goals define in more detail the desired state of the problem, they are developed prior to alternative identification. Goals are useful in identifying superior alternatives.

   Sometimes goals may conflict, but this is neither unusual, nor cause for concern. During goal definition, it is not necessary to eliminate conflict among goals, or to define the relative importance of the goals. Establishing goals may suggest new or revised requirements or requirements may be converted to goals. In any case, understanding the requirements and goals is important to defining alternatives.

4. **Identify Alternatives-** Alternatives change the initial condition into the desired condition. The decision team evaluates the requirements and goals and suggests alternatives that will meet the requirements and satisfy as many goals as possible. Generally, the alternatives vary in their ability to meet the requirements and goals. Those alternatives that do not meet the requirements must be screened out from further consideration. If an alternative does not meet the requirements, three actions are available:
   - The alternative is discarded
   - The requirement is eliminated
   - The requirement is restated as a goal

The description of each alternative must clearly show how it solves the defined problem and how it differs from the other alternatives. A written description and a diagram of the specific functions performed to solve the problem will prove useful.

5. **Define Criteria** - Usually no one alternative will be the best for all goals, so the alternatives must be compared with each other. The best alternative will be the one that most nearly achieves the goals. It is necessary to define discriminating criteria as objective measures of the goals to measure how well each alternative achieves the project goals.

   Each criterion should measure something important, and not depend on another criterion. Criteria must discriminate among alternatives in a meaningful way (e.g., if the color of all alternatives is the same or the user is indifferent to the color selection, then color should not be a criterion).
   Criteria should be:
   - Able to discriminate among the alternatives
   - Complete – include all goals
   - Operational – meaningful to the decision maker to understand the implications of the alternatives
   - Non-redundant – avoid double counting
   - Few in number – to keep the problem dimensions manageable

   Using a few real discriminators will result in a more understandable decision analysis product. However, every goal must generate at least one criterion. If a goal does not suggest a criterion, it should be abandoned.

   Several methods can be used to facilitate criteria selection.

   Brainstorming: Team brainstorming may be used to devlop goals and associated criteria.

   Round Robin: Team members are individually asked for their goals and criteria associated with them. The initial elicitation of ideas should be done non-judgmentally - all ideas are recorded before criticism of any is allowed.

   When members of the goal-setting group differ widely in rank or position, it can be useful to employ the military method in which the lowest ranking member is asked first to avoid being influenced by the opinions of the higher-ranking members.

6. **Select Decision-Making Tool -** Six types of tools most commonly used by decision-makers are:

   - Pros and Cons Analysis
   - Kepner-Tregoe Decision Analysis
   - Analytic Hierarchy Process
   - Multi-Attribute Utility Theory Analysis
   - Cost Benefit Analysis
   - Custom Tailored Tools

   Some of these methods can be complicated and difficult to apply. The method selection needs to be based on the complexity of the problem and the experience of the team. The simpler the method, the better. More complex analyses can be added later if needed.